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**EDGEWOOD ARSENAL**

**TECHNICAL REPORT**

**EATR 4075**

**THE EFFECTS OF THERMALLY-GENERATED  
CS AEROSOLS ON HUMAN SKIN**

by

Alfred Hellreich, CPT, MC  
Richard H. Goldman, CPT, MC  
Nicholas G. Bottiglieri, LTC, MC  
John T. Weimer

January 1967



**Medical Research Laboratory  
Research Laboratories  
EDGEWOOD ARSENAL  
EDGEWOOD ARSENAL, MARYLAND 21010**

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**Task IC622401A09708**

**Medical Research Laboratory  
Research Laboratories  
EDGEWOOD ARSENAL  
EDGEWOOD ARSENAL, MARYLAND 21010**

## FOREWORD

The work described in this report was authorized under Task 1C622401A09708, General Investigations (U) and was partially supported by Deseret Test Center. This work was started in May 1966 and completed in June 1966. The experimental data are contained in case histories 4116, 4119, 4120, 4123, 4124, 4127, 4131, 4144, 4153, 4158, 4174, 4186, 4192, 4206, and 4216, which are maintained in the files of the Clinical Research Department.

The human subjects in the tests conducted by this installation are enlisted US Army volunteers. There is no coercion or enticement to volunteer. The most stringent medical safeguards surround every human test.

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## Acknowledgments

The authors express their appreciation to Edmund J. Owens, Chief, Aerosol Branch, Toxicology Department, and Ronald Merkey of Aerosol Branch for their assistance.

### DIGEST

In order to determine whether o-chlorobenzylidene malononitrile (CS) aerosols, under tropical climatic conditions, offer any threat to the nonsensitized human integument, volunteers were exposed to high concentrations of CS for periods up to 1 hr. Second degree chemical burns occurred in four of the eight subjects exposed to a Ct of 14,040 or 17,700.

It was generally noted that the volunteers most susceptible to sunburn (e. g., blue-eyed blondes as opposed to non-Caucasians) displayed the most severe reactions, even though ultraviolet light was not a factor in our study. It was also noted that the healing of minor wounds (scratches and needle marks) was not affected by the CS burns. Areas covered by fatigue uniform sleeves remained reaction-free in all cases, demonstrating the protective effect of the dry uniform.

It was concluded that:

1. Very high Ct's of CS (> 14,000) under tropical conditions of heat and humidity (with moderate wind velocity) produce vesication of human skin.
2. The disability produced by these second degree chemical burns is treatable but may incapacitate the recipient for up to 10 days.

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## THE EFFECTS OF THERMALLY-GENERATED CS AEROSOLS ON HUMAN SKIN

### I. INTRODUCTION.

Direct patch tests of o-chlorobenzylidene malononitrile (CS) powder,<sup>1, 2</sup> CS aqueous paste,<sup>2</sup> and CS-methylene dichloride solution<sup>1</sup> have demonstrated the primary irritant and vesicant potentials of CS on human skin; however, many chemicals, including some soaps and detergents, will cause patch-test reactions even though they are perfectly harmless in ordinary (diluted) use.<sup>3</sup>

A review of dermatologic complications suffered by CS workers<sup>4</sup> and personal observations in treating such cases reveal a low incidence of direct chemical irritation by CS, in contrast to its high skin-sensitizing potential (antigenicity). In addition, factors such as heat, moisture, and a fair complexion have been implicated in producing or accentuating irritation.<sup>2, 4</sup>

When the present study was undertaken, no dermatologic studies of the aerosol form of CS had been reported and no significant skin reactions in workers or volunteers exposed to these aerosols had been brought to our attention. Moreover, human aerosol studies had been made with very low concentrations of CS.<sup>1, 5</sup>

In order to determine whether CS aerosols, under tropical climatic conditions, offer any threat to the nonsensitized human integument, volunteers were exposed to high concentrations of CS for periods up to 1 hr.

### II. PROCEDURE.

Four groups of four medical volunteers each were used in this study. The right arms of the subjects in each group were exposed (figure 1, appendix A\*) to thermally-generated CS aerosols (M7 munitions) in a test chamber specially constructed to maintain constant conditions of temperature (97°F), humidity (100%), and wind velocity (5 mph). The CS grenades were fired in a separate chamber, and the resulting aerosol was blown into the test chamber. The grenades were fired in the following sequence:

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\* All figures are in appendix A.



1. The first grenade was detonated 1 min prior to exposure.
2. The second grenade was detonated 7 min after beginning of exposure.
3. The subsequent grenades were detonated at 10-min intervals thereafter for duration of exposure time.

Air samples were drawn at periodic intervals during exposure to determine the concentration of CS (figure 2). From these data, the average concentration and  $Ct^*$  were determined for each of the four groups of men. The exposure time for the groups were 15, 30, 45, and 60 min, respectively.

The left arm of each test subject was exposed to the same climatic conditions and for the same period of time as the right arm, but no agent was disseminated during these tests. (The only variation from this procedure was in the 45-min test group, in which the control arm was exposed for 90 min.)

### III. RESULTS.

#### A. Control Arms.

The climatic conditions alone produced mild, transient vascular changes in the control arms of most subjects.

1. Symptoms.

None.

2. Signs.

Varying degrees of patchy erythema, which blanched on pressure, could be detected. This slight reticular erythema (livedo reticularis) occurred within 1 min after the control arm was removed from the test chamber and always disappeared within 15 min. With one exception, no epidermal reaction was noted, the effect being entirely vascular and confined to the dermis. Examination of all control arms for as long as 3 wk after exposure showed them to be entirely normal.

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\*  $Ct$  is concentration in milligrams per cubic meter times time in minutes (mg min/cu m).

Table. Skin Reactions of Arms Exposed to CS

Average concentration	t	Ct	Volunteer number	Case number	Immediate erythema (dermal)	Delayed erythema (epidermal)	Vesiculation
mg/cu m	min	mg min/cu m					
296	15	4,440 (Group I)	1	4,123	+++	-	-
			2	4,127	+	-	-
			3	4,144	+	-	-
			4	4,131	+	-	-
315	30	9,480 (Group II)	5*	4,124	-	-	-
			6	4,116	+++	+	-
			7	4,120	(±)**	-	-
			8	Coauthor (RHG)	(±)	-	-
312	45	14,040 (Group III)	9	4,158	+++	+++	+++
			10	4,119	+++	+++	-
			11	4,174	+++	+	-
			12	4,206	+++	++	-
295	60	17,700 (Group IV)	13	4,153	+++	+++	++
			14	4,216	++	+	+
			15*	4,192	+++	+++	(±)
			16	4,186	++	+	++

\* Negro volunteers.

\*\* (±) = equivocal.

Because of the marked delayed reaction that occurred unexpectedly in groups III and IV, this study was immediately discontinued to preclude serious injury to the volunteer subjects.

### 3. Treatment.

Volunteers No. 9 (figure 4), 13 (figure 6), and 16 (figure 7) who demonstrated the most severe burns, were treated to avoid secondary infection, scarring, or both. The largest vesicles were incised, and the subjects were hospitalized for 1 wk, during which time open compresses of cold silver nitrate (1:1000) solution were applied for 1 hr, six times a day.

Volunteer No. 9, who displayed the greatest degree of edema, vesiculation, and discomfort, was also placed on a short course of oral prednisone and overnight applications of bacitracin ointment. Systemic administration of antibiotics was not required. No infections occurred, and epithelization took place within 10 days.

Six-week followup revealed no sequelae except a mild post-inflammatory hyperpigmentation, which is expected to fade eventually (figure 4I). It was also noted that the healing of minor wounds (scratches and needle marks) was not affected by the CS burns.

It should be emphasized that without adequate treatment, especially under field conditions, severe local infections would be expected in a large proportion of second degree burns, producing concomitant complications and further incapacitation.

## IV. DISCUSSION.

It was generally noted that the volunteers most susceptible to sunburn (e.g., blue-eyed blondes as opposed to non-Caucasians) displayed the most severe reactions, even though ultraviolet light was not a factor in our study. This observation raises the question of whether melanin may be a factor in the body's natural protection against chemical irritants. It must be emphasized, however, that no definite conclusions as to susceptibility can be drawn from this limited number of cases.

Areas covered by fatigue uniform sleeves remained reaction-free in all cases, demonstrating the protective effect of the dry uniform. Further studies to devise topical protectants for exposed areas of skin are in progress.

Since this study was done, the fact that accidental burns have resulted when military personnel on maneuvers were exposed to a cloud of CS has been brought to our attention. Ambient environmental conditions when the accident occurred were similar to those maintained in the exposure chamber during the present study. A brief description of the accident is contained in appendix B.

V. CONCLUSIONS.

1. Very high Ct's of CS (> 14,000) under tropical conditions of heat and humidity (with moderate wind velocity) produce vesication of human skin.

2. The disability produced by these second degree chemical burns is treatable but may incapacitate the recipient for up to 10 days.

### LITERATURE CITED

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APPENDIX

FIGURES



Figure A1. One Group of Volunteers Exposing  
Right Arms in Test Chamber

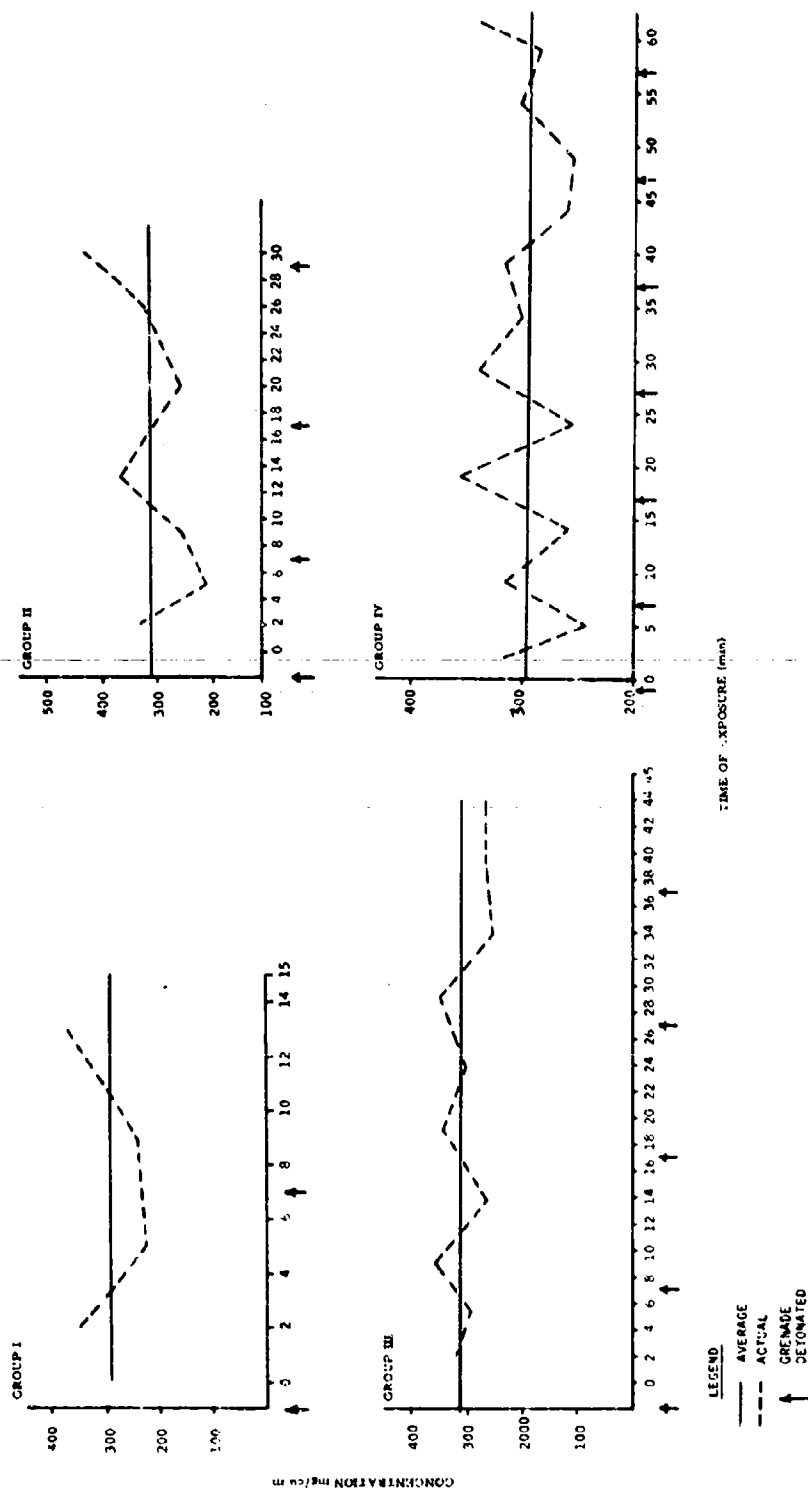


Figure A2. Concentration of CS in Chamber

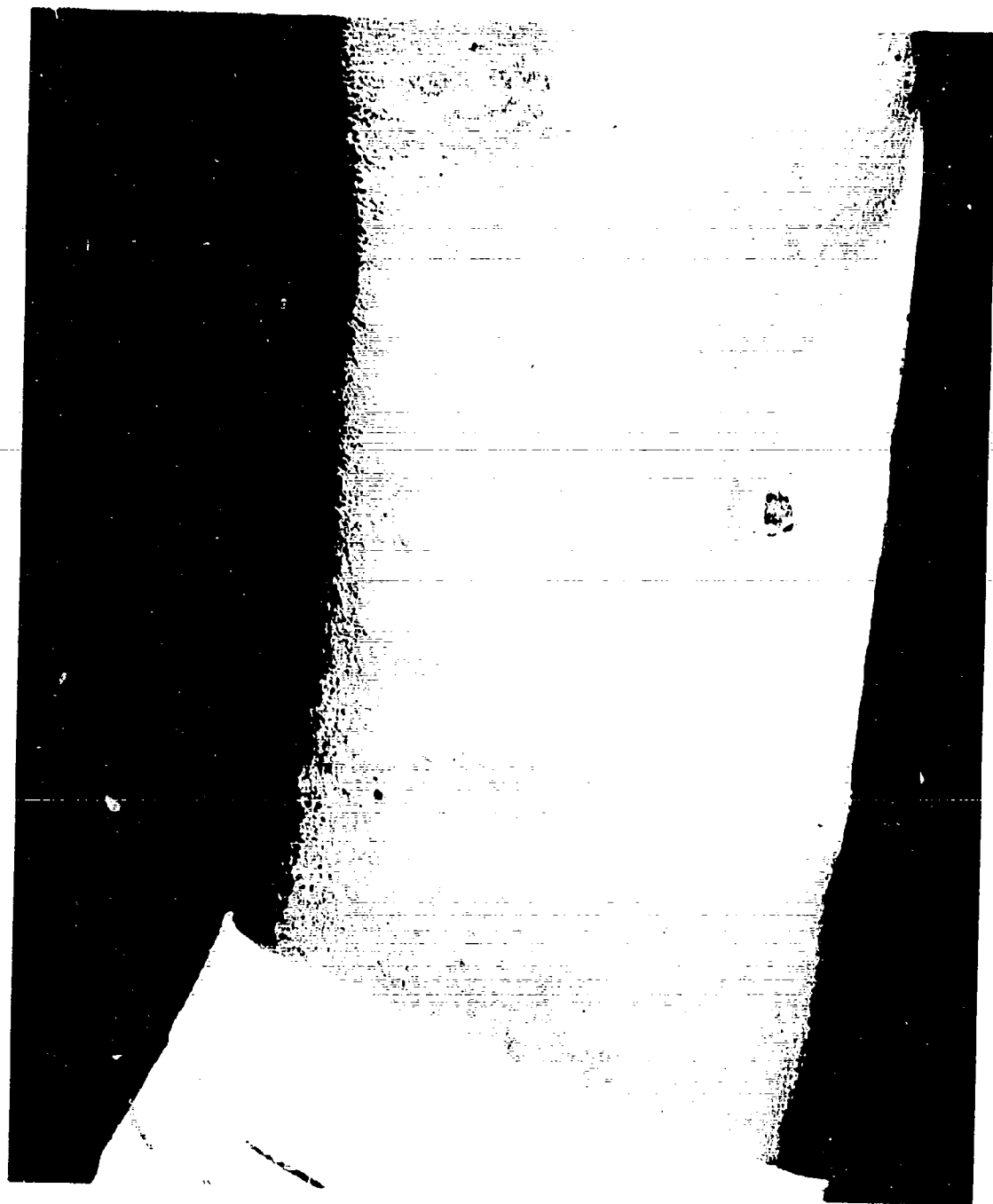
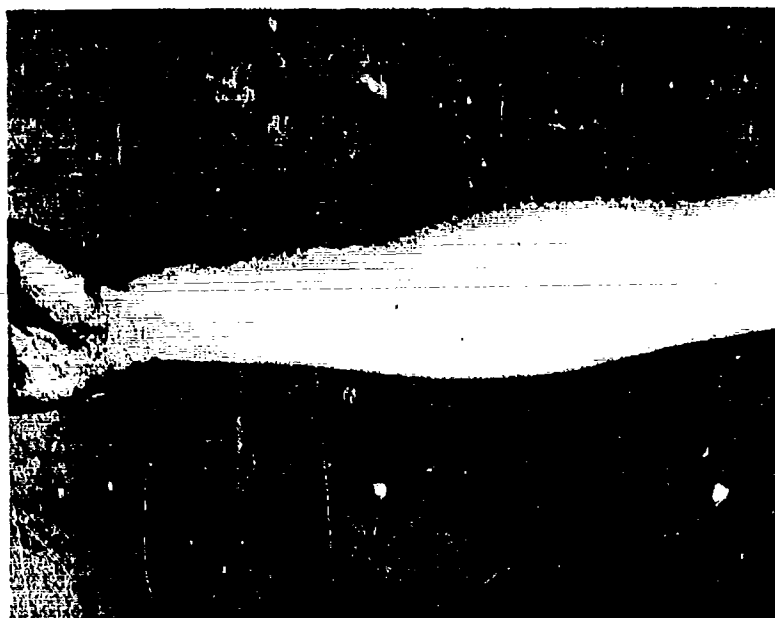


Figure A3. Band of Vesiculation Around Control Arm of Volunteer No. 9 at 45 hr After 90-min Exposure to Tropical Climatic Environment

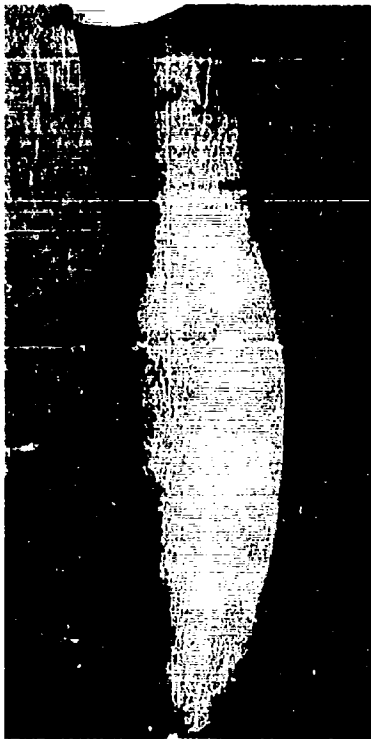




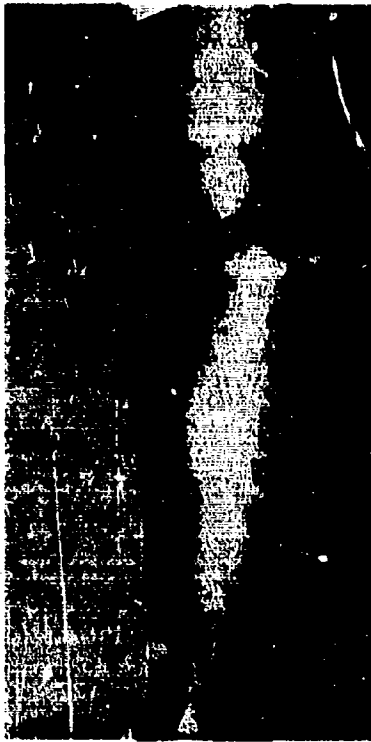
A. Test Arm Before Exposure

Figure A4. Sequential Photographs of Volunteer No. 9, Who Demonstrated the Most Severe Reaction

Note the evolution of blistering between 20 hr (C) and 25 hr (D). Treatment was begun at 45 hr, just after photograph E was taken. The subsequent grayish discoloration is the result of silver nitrate compresses.



B. 10 min After Exposure



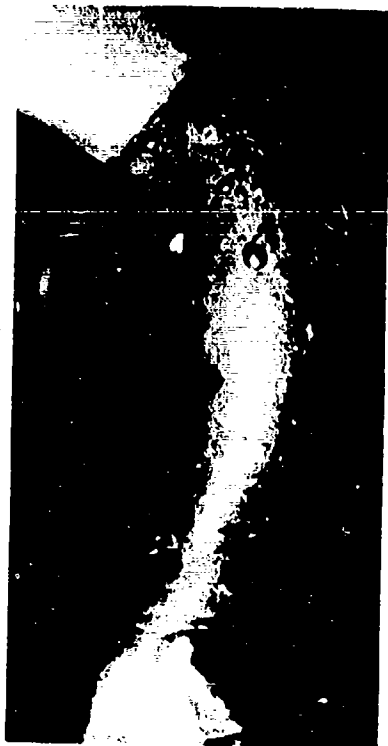
C. 20 hr After Exposure



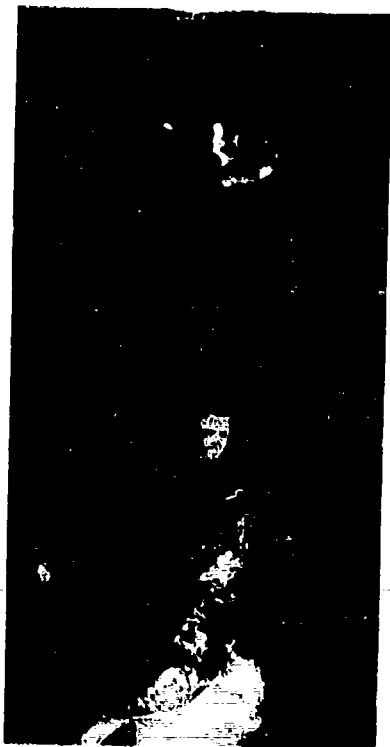
D. 25 hr After Exposure



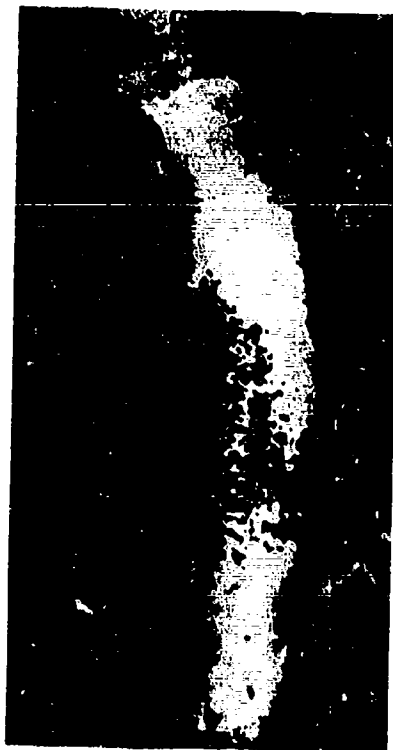
E. 45 hr After Exposure



F. 70 hr After Exposure (Under Treatment)



G. 8 Days After Exposure



H. 14 Days After Exposure



I. 6 Weeks After Exposure



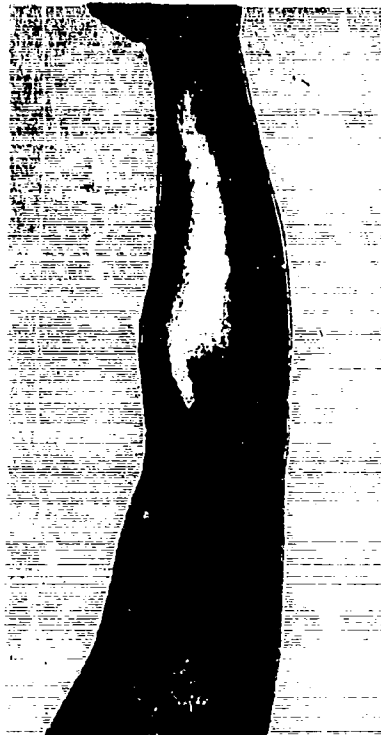
A. 24 hr Postexposure



B. 45 hr Postexposure



C. 9 Days Postexposure



D. 15 Days Postexposure

Figure A5. Volunteer No. 15, a Negro, Displayed the Mildest Reaction of Group IV

Diffuse crusting on the arm, secondary to almost imperceptible tiny vesicles, can be seen in C and D. A transient miliaria rubra developed but is not demonstrated in these photographs.

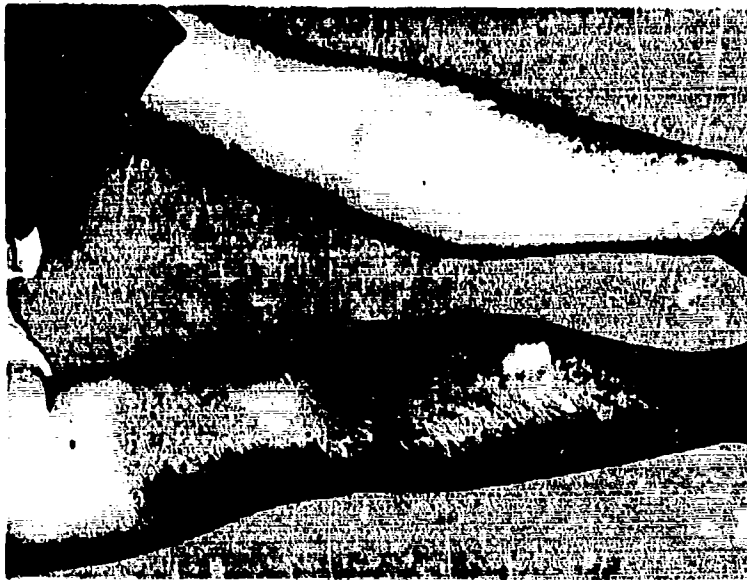


Figure A6. Control Versus Test Arm 24 hr Postexposure

A four-plus delayed reaction (first degree burn) occurred in volunteer 13. This was followed the next day with some vesiculation. The control arm, after undergoing a mild immediate erythema, is completely normal.



A. 20 hr Postexposure

Figure A7. Closeups of the Exposed Hand of Volunteer No. 16  
Illustrate the Time Sequence of Evolution of Vesiculation

Note that his recent scratch marks were not affected.



B. 25 hr Postexposure



C. 45 hr Postexposure



D. 60 hr Postexposure



E. 15 Days Postexposure

## APPENDIX B

### REPORT OF ACCIDENTAL CS BURNS IN A FIELD EXERCISE\*

First and second degree CS burns, similar to those produced in the experiment described in the preceding text, were accidentally produced in a group of Chemical Corps officers participating in a field exercise at Ft. McClellan, Alabama, on 4 August 1966.

The officers were dressed in standard fatigue uniforms, ponchos, gloves, and M17 protective masks. They had been in the field for several days, and their clothes were thoroughly soaked from a heavy 10- to 12-hr rain. As they approached a road block (their mission was to capture it) between 2000 and 2030 hr, micropulverized CS-1 was directed toward them from a portable disperser—a modified flamethrower. Because of the rain, the CS hung in the air as a heavy cloud. It completely enveloped 12 men and contacted others (some of whom were not wearing masks) at the periphery.

After the immediate effects of the aerosol had worn off, the men continued with their mission but noted burning of the skin in areas that were not protected by the poncho, gloves, mask, and boots; namely, the V area of the neck, the forearms, the wrists, and the calves. The CS powder seemed to soak through the wet fatigues.

At 2300 to 2400 hr, one of the officers that had been completely enveloped by the cloud and seven that had been on the periphery were hosed, and they changed into fresh uniforms.

#### Clinical Course.

Marked erythema appeared on the V area of the neck, the forearms, the wrists, and the calves by 0300 to 0600 hr 5 August 1966, which was 7 to 10 hr after exposure. [This corresponded clinically to the delayed erythema (first degree burns) encountered in our volunteer subjects]. By 1000 to 1200 hr

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\* This appendix was prepared from information furnished the authors by CPT Joseph F. Hollinger, MC, Noble Army Hospital, Fort McClellan, Alabama (the medical officer who treated these cases) and by 1LT Charles P. O'Farrell, CMLC, Edgewood Arsenal, Maryland, one of the participants in the exercise.

(14 to 16 hr after exposure), blistering had begun in the most severe cases. All of the 12 men caught in the cloud eventually developed various degrees of vesiculation that corresponded clinically to the second degree burns produced experimentally. The one who had been hosed and who had changed clothes had milder burns than those sustained by the others. About half of the men who were at the periphery of the CS cloud developed first or second degree burns, but none of those who were hosed had blisters.

#### Treatment.

Those who received second degree burns were treated with tetanus toxiod, topical bacitracin ointment, and Furacin dressings. Large bullae were opened surgically. Systemic administration of antibiotics was not required, and all vesicles epithelialized in about 1 week. No sequellae were reported.



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DOCUMENT CONTROL DATA - R&D		
(Security classification of title, body of abstract and indexing annotation must be entered when the overall report is classified)		
1. ORIGINATING ACTIVITY (Corporate author) CO, Edgewood Arsenal ATTN: SMUEA-RMC Edgewood Arsenal, Maryland 21010		2a. REPORT SECURITY CLASSIFICATION UNCLASSIFIED
		2b. GROUP N/A
3. REPORT TITLE THE EFFECTS OF THERMALLY-GENERATED CS AEROSOLS ON HUMAN SKIN		
4. DESCRIPTIVE NOTES (Type of report and inclusive dates) This work was started in May 1966 and completed in June 1966.		
5. AUTHOR(S) (Last name, first name, initial) Hellreich, Alfred, CPT, MC Goldman, Richard H., CPT, MC Bottiglieri, Nicholas G., LTC, MC Weimer, John T.		
6. REPORT DATE January 1967	7a. TOTAL NO. OF PAGES 40	7b. NO. OF REFS 5
8a. CONTRACT OR GRANT NO.  a. PROJECT NO.  c. Task IC622401A09708 d.	9a. ORIGINATOR'S REPORT NUMBER(S) EATR 4075  9b. OTHER REPORT NO(S) (Any other numbers that may be assigned this report) N/A	
10. AVAILABILITY/LIMITATION NOTICES Each transmittal of this document outside the agencies of the US Government must have prior approval of the Commanding Officer, Edgewood Arsenal, ATTN: SMUEA-TSTI-T, Edgewood Arsenal, Maryland 21010.		
11. SUPPLEMENTARY NOTES General Investigations	12. SPONSORING MILITARY ACTIVITY N/A	
13. ABSTRACT In order to determine whether CS aerosols, under tropical climatic conditions, offer any threat to the nonsensitized human integument, volunteers were exposed to concentrations of CS for periods up to 1 hr. Second degree chemical burns occurred in four of the eight subjects exposed to a Ct of 14,040 or 17,700. It was generally noted that the volunteers most susceptible to sunburn (e.g., blue-eyed blondes as opposed to non-Caucasians) display the most severe reactions, even though ultraviolet light was not a factor in our study. It was also noted that the healing of minor wounds (scratches and needle marks) was not affected by the CS burns. Areas covered by fatigue uniform sleeves remained reaction-free in all cases, demonstrating the protective effect of the dry uniform. Very high Ct's of CS (> 14,000) under tropical conditions of heat and humidity (with moderate wind velocity) produce vesication of human skin. The disability produced by these second degree chemical burns is treatable but may incapacitate the recipient for up to 10 days.		

DD FORM 1473  
1 JAN 64

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#### 14. KEYWORDS

CS

Aerosol

Vesicant

Chemical burns

Tropical climatic conditions

Irritant agent

Riot-control agent

Skin (human)

Complexion

Climatic chamber

Accidental burn

Field maneuver

Errata for AD 802 485

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A thin band of epidermal reaction (persistent erythema and subsequent vesiculation) appeared 3 in. above the left elbow of volunteer no. 9 (figure 3). This was felt to be caused by persistence of traces of CS powder around the arm off of the chamber. It should be noted that this volunteer's left arm was exposed for 90 min. In no other instance did this phenomenon occur.

## B. Exposed Arms.

A spectrum of signs and symptoms was observed when the subjects were exposed to CS. They varied from no significant reaction to severe second degree burns, correlating (to some extent) with the CI and with the complexion of the volunteer.

### 1. Symptoms.

All volunteers uniformly noted stinging of the exposed forearm, beginning 5 to 10 min after exposure was begun. Immediately after being withdrawn from the chamber, their arms were rinsed with cold running water for 1 min to remove most of the white CS powder that visibly clung to the hairs. The stinging increased moderately on washing but subsided within the next 5 min.

### 2. Signs.

CIs of 1,440 and 2,480 induced an immediate skin response in all except volunteer No. 4, a Negro (table). This began 1 min after exposure as a patchy vascular dermal erythema, more prominent than that of the control arms. The erythema became confluent, persisted for 10 to 30 min, and produced no discernible sequelae.

CIs of 14,040 and 17,700 induced a more severe immediate dermal response, which subsided within 3 hr. In addition, a delayed reaction appeared 12 to 24 hr later in all cases: this consisted of first and second degree burns. Both epidermis and dermis were involved, the epidermal reaction predominating. Blistering occurred in four of the eight volunteers in groups III and IV.

Volunteer No. 9, a blue-eyed blonde who sunburns easily, developed the most severe reaction (figure 4). Volunteer No. 15, the other participating Negro, developed borderline (equivocal) vesiculation, which was followed in 4 days with miliaria rubra (prickly heat) (figure 5). In many instances, the sleeve of the fatigue uniform worn by the subjects covered some portion of the upper arm that was in the chamber. These covered areas did not have reactions.

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